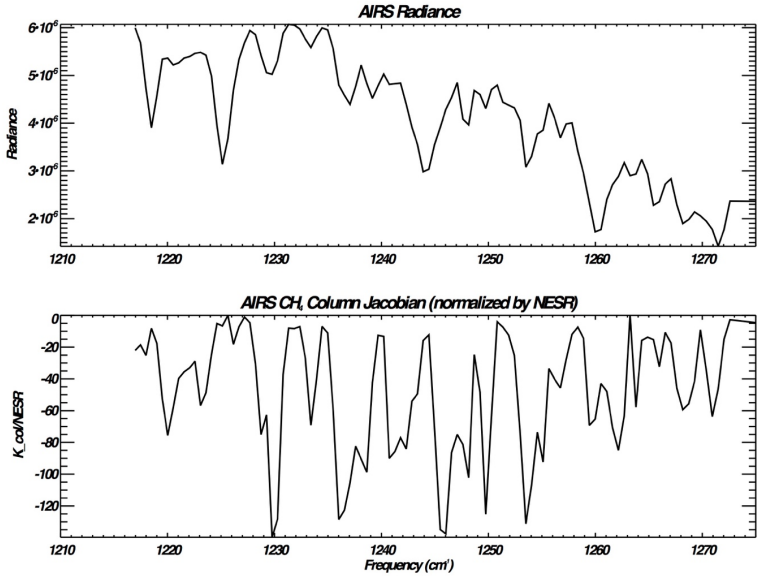
Characterizing Process Controls of the Carbon and Water Cycle Using a Multi-Decadal Record of HDO, H_2O, CH_4, and CO from AIRS, TES, and CRIS

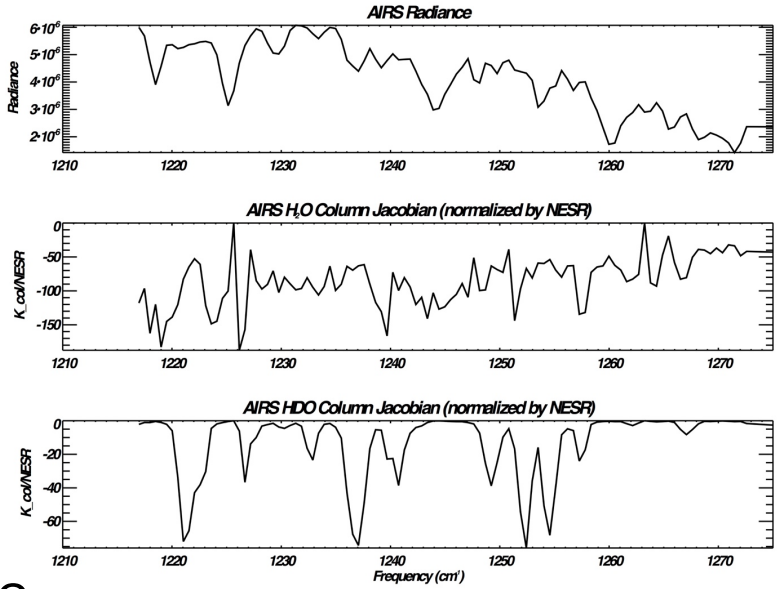
John Worden Presenting

TIR radiances at 8 and 4 microns are highly sensitive to atmospheric CH_4, HDO, H_2O, and CO concentrations

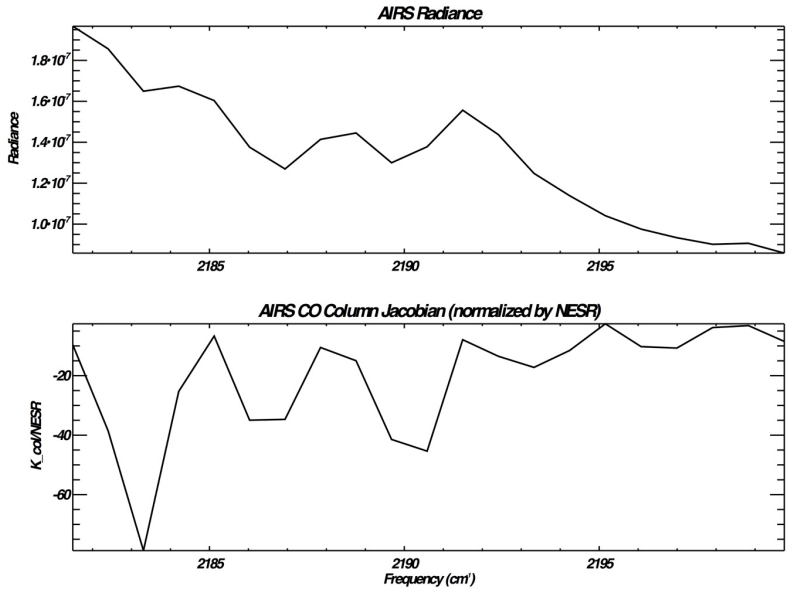
Sensitivity to CH_4



Sensitivity to H_2O and HDO

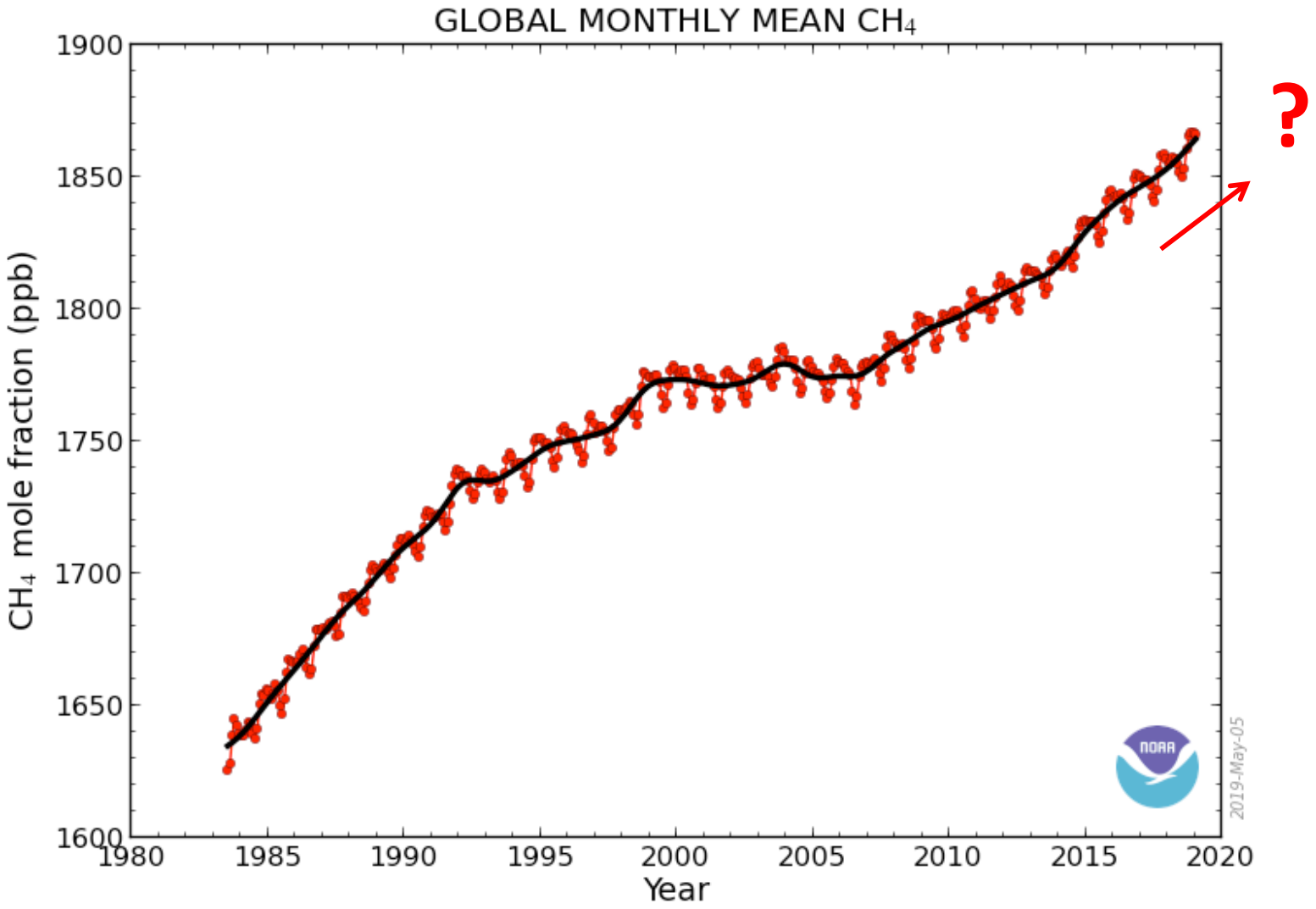


Sensitivity to CO



Fu et al. 2018
Worden et al. 2019
Kulawik et al. in preparation

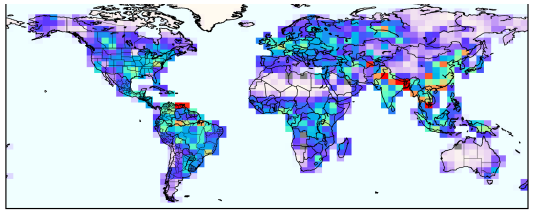
Q1: Why are Methane Concentrations and Its Growth Rate Increasing?



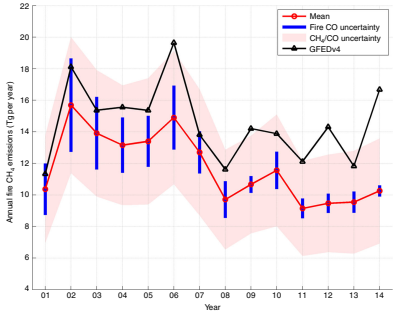
A challenging puzzle: How do we disentangle the sources and sinks of Methane using Satellite, aircraft, and ground data sets ?

Courtesy D. Jacob

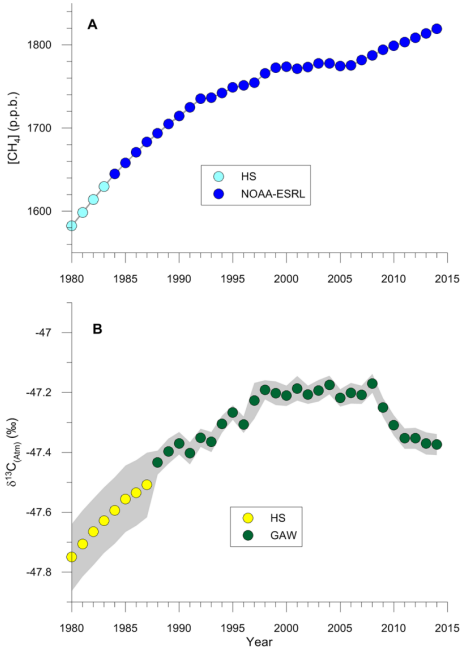
Satellite based fluxes to constrain spatial distribution of sources



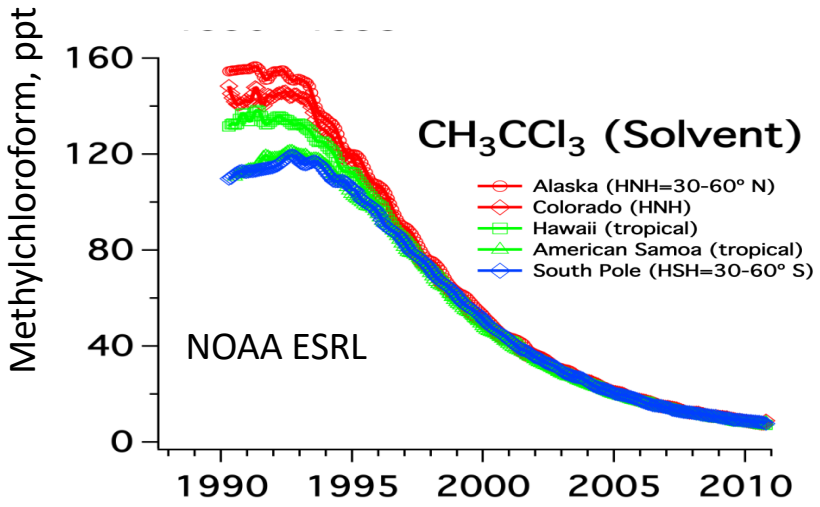
Satellite observations of fires from NASA MODIS / MOPITT



Surface methane and isotopes to partition fossil, biogenic, and pyrogenic sources



Uncertainty in Chemical Sink is As Large As Individual Source Terms



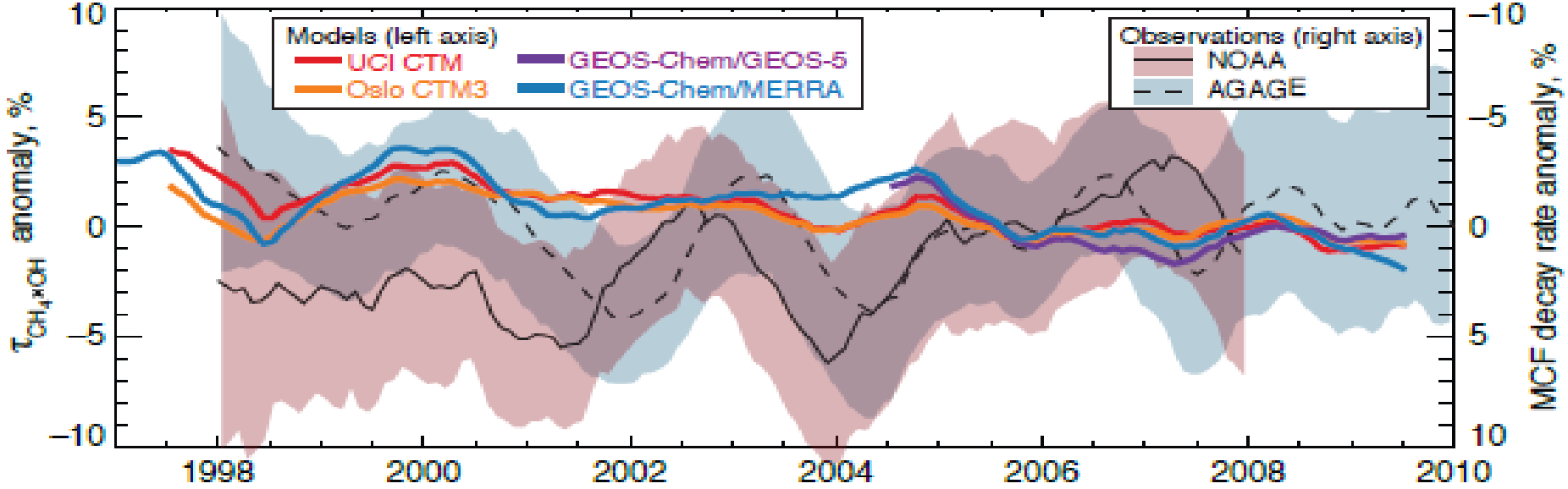
"traditionally" we have used atmospheric methylchloroform to monitor the sink

Mass balance for methylchloroform:

$$\frac{dm_{MCF}}{dt} = -k\overline{[\mathrm{OH}]}\, m_{MCF} + \text{minor terms}$$

Low Methylchloroform Concentrations Past 2010

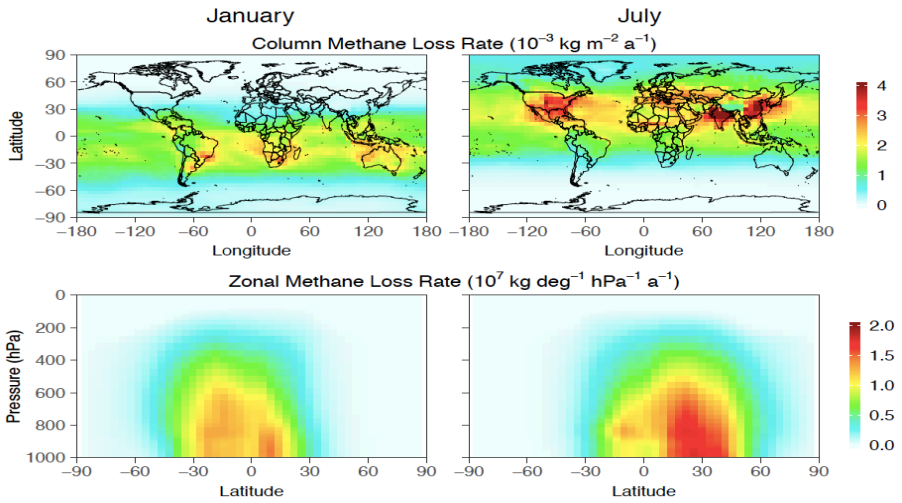
OH variability and uncertainty are ~5% based on methylchloroform data



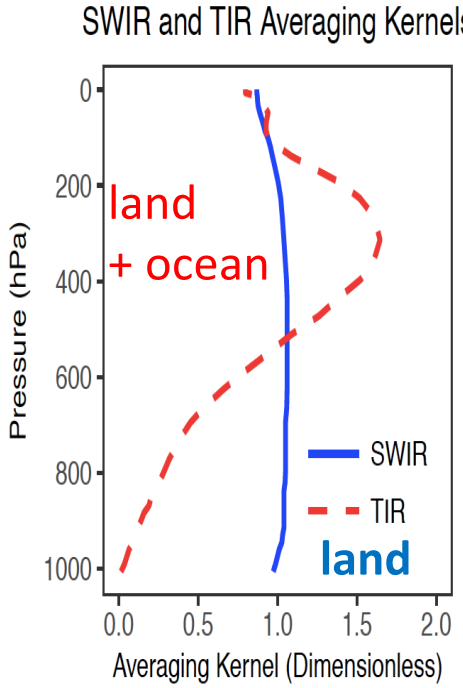
Holmes et al. [2013], Turner et al. [2017], Rigby et al. [2017}

Can we use TIR Methane to monitor changes in OH (the methane chemical sink)?

Vertical resolution and sampling of TIR CH_4 must be different than total column to distinguish OH from Emissions



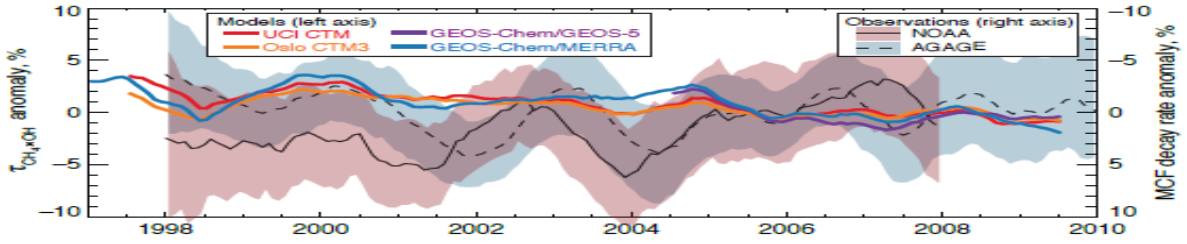
Zhang et al. [2018]



TIR CH_4 sensitive over ocean and less sensitive to emissions

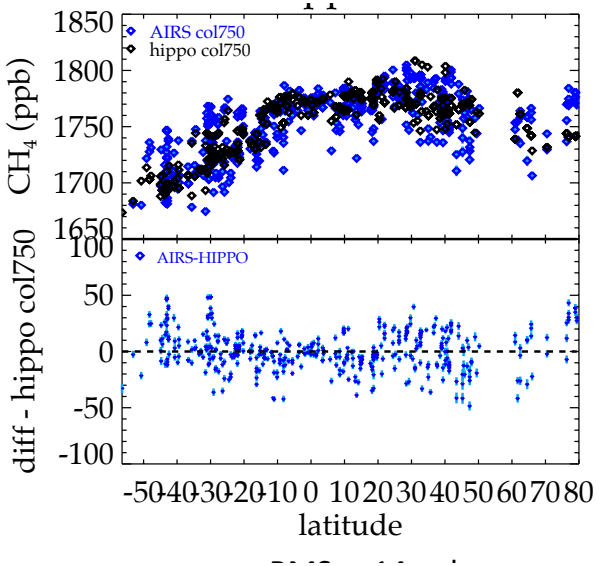
NIR more sensitive to emissions

Accuracy of an OH estimate is ideally better than 3%

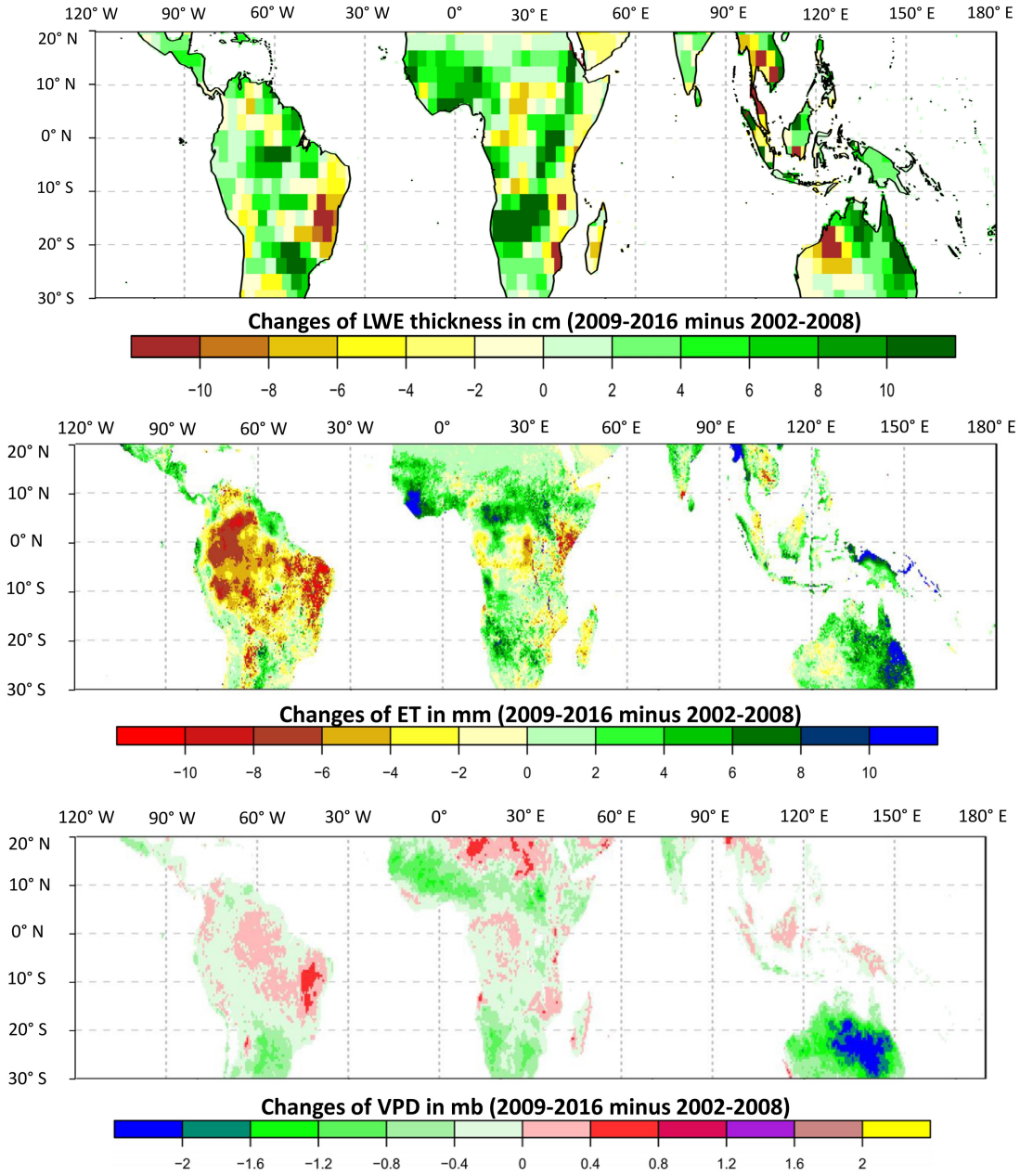


Holmes et al. [2013], Turner et al. [2017], Rigby et al. [2017}

Accuracy ~0.8% over Ocean Based on HIPPO Comparisons



Is the Balance of Ocean and Land Moisture Sources Over the Tropics Changing?



Rodell et al. 2019, Barkhordarian et al. submitted. Also thanks to M. Shi, JT Reager, and J. Fisher for figures

Satellite Observations of Total Water Storage (GRACE), Vapor Pressure Deficit (AIRS), and Evapotranspiration (MODIS / Reanalysis) tell a complex story about the tropical water cycle from 2002 - 2016

Dry Tropics Make Sense

Increasing / Decreasing TWS are Paired with Decreasing / Increasing VPD and Increasing / Decreasing ET

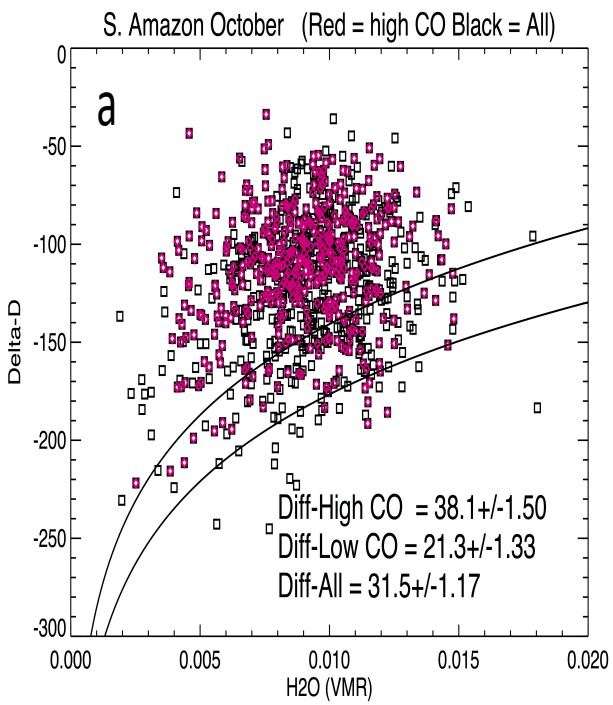
Wet Tropics Don't Make Sense!

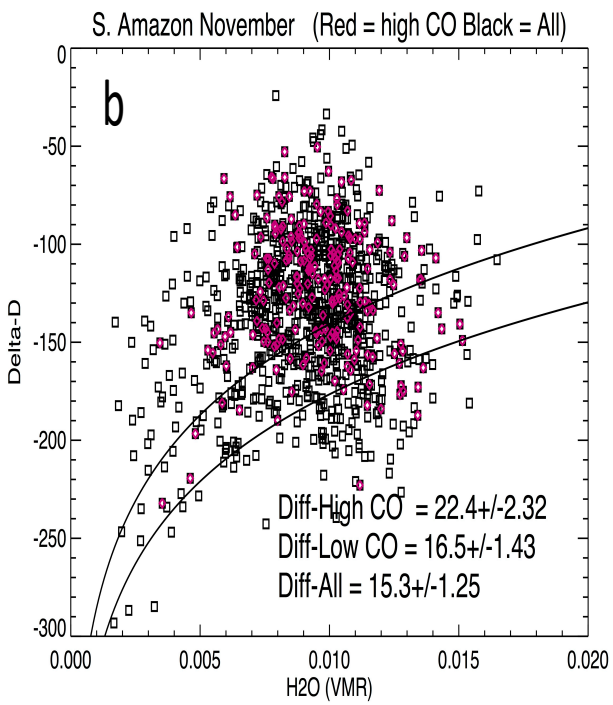
What is going on?
Change In Circulation? Residence time of C / W? Water Capacity? Evapotranspiration? River Runoff?

Measurements of the isotopic composition of water vapor can provide another clue

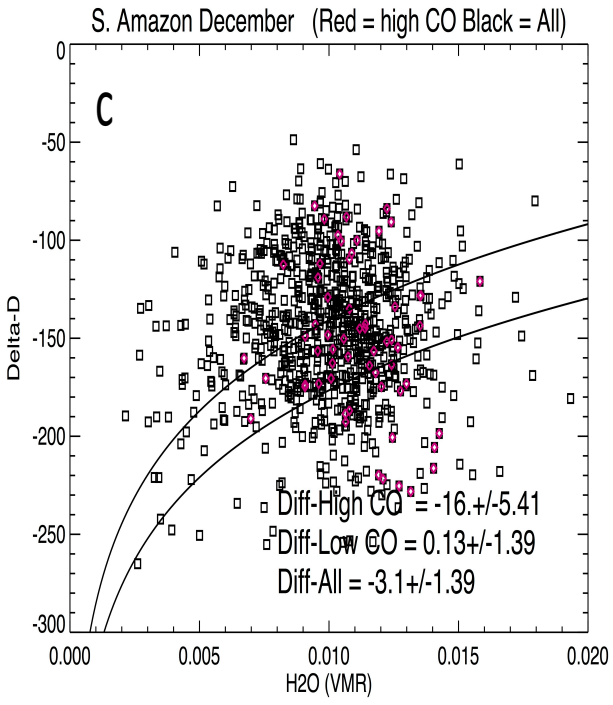
Satellite TIR Measurements of Water Vapor Isotopes Are Sensitive to Land and Ocean Moisture Sources and Deep Convection and Their Seasonal Variability

Pre Rainy Season





Rainy Season

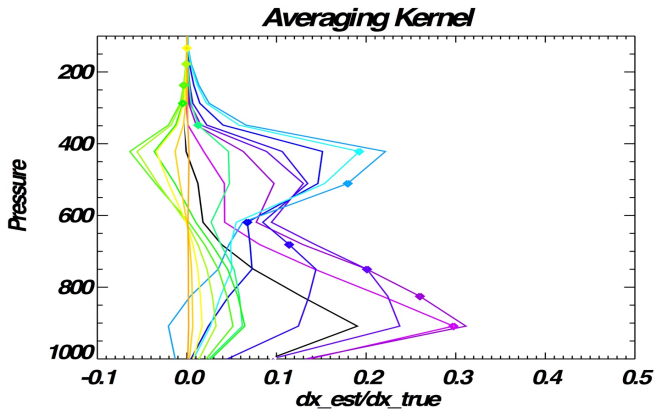


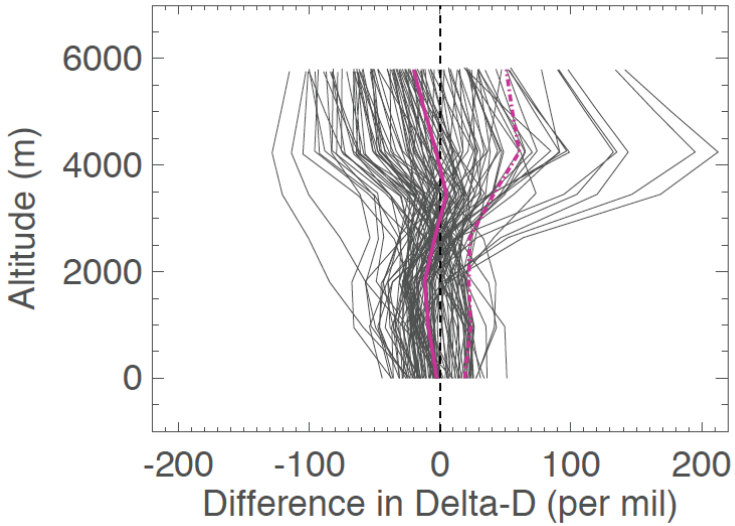
More Transpiration,
No Convection

Less Transpiration,
Lots of Convection

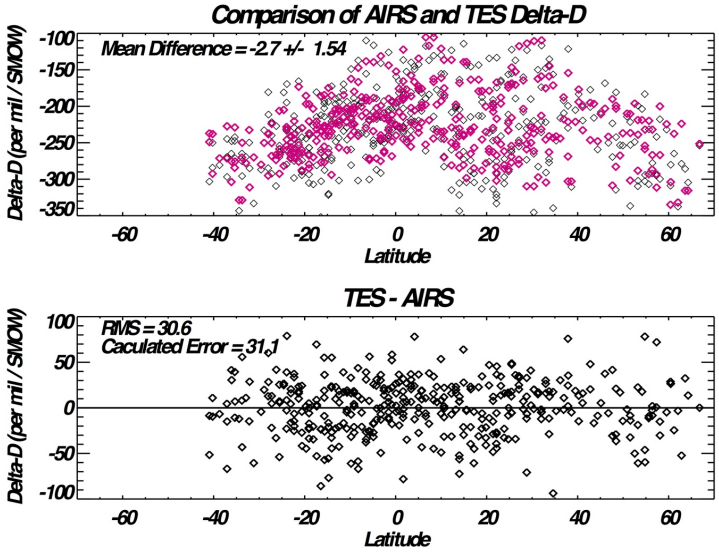
A Record of AIRS, TES, and CRIS HDO and H_2O Can Provide Another Clue About the Changing Tropical Water Cycle

AIRS data has 1-2 DOFS in Tropics





Calculated Errors of ~25 per mille and ~-2.0 bias via comparisons against TES



AND Aircraft
(ORACLES WHISPERS D. Noone PI)

Herman et al. AMTD submitted

Summary and Conclusions

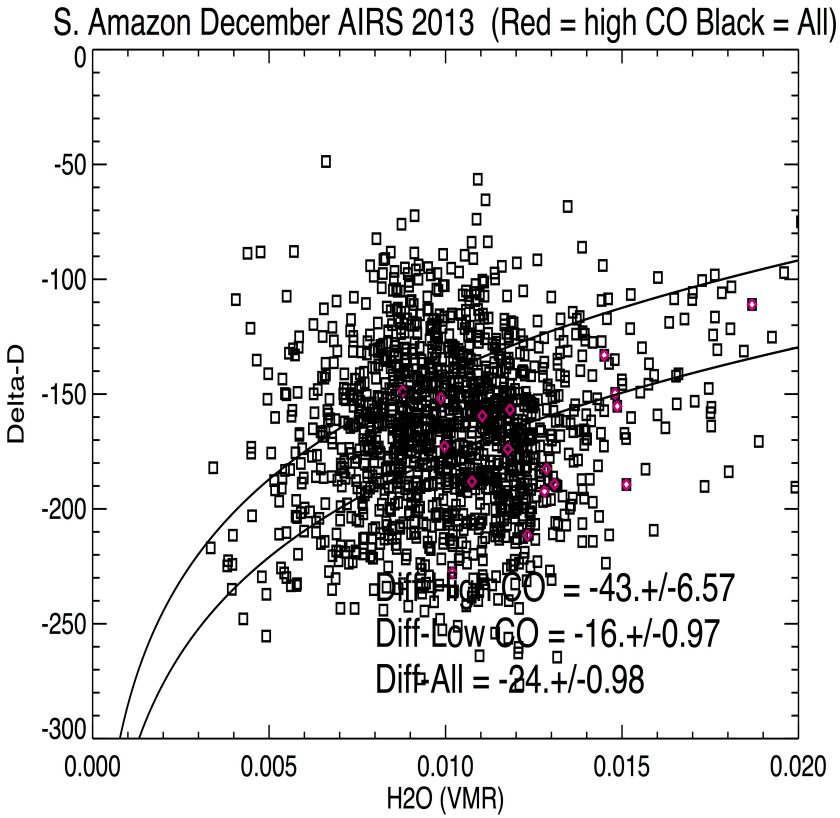
- Large Variations are observed in the Tropical Carbon And Water Cycles during the 21rst century

- AIRS, TES, and CRIS radiances can be used to generate a robustly characterized record of key carbon and water tracers (CH4, HDO, H2O, and CO)

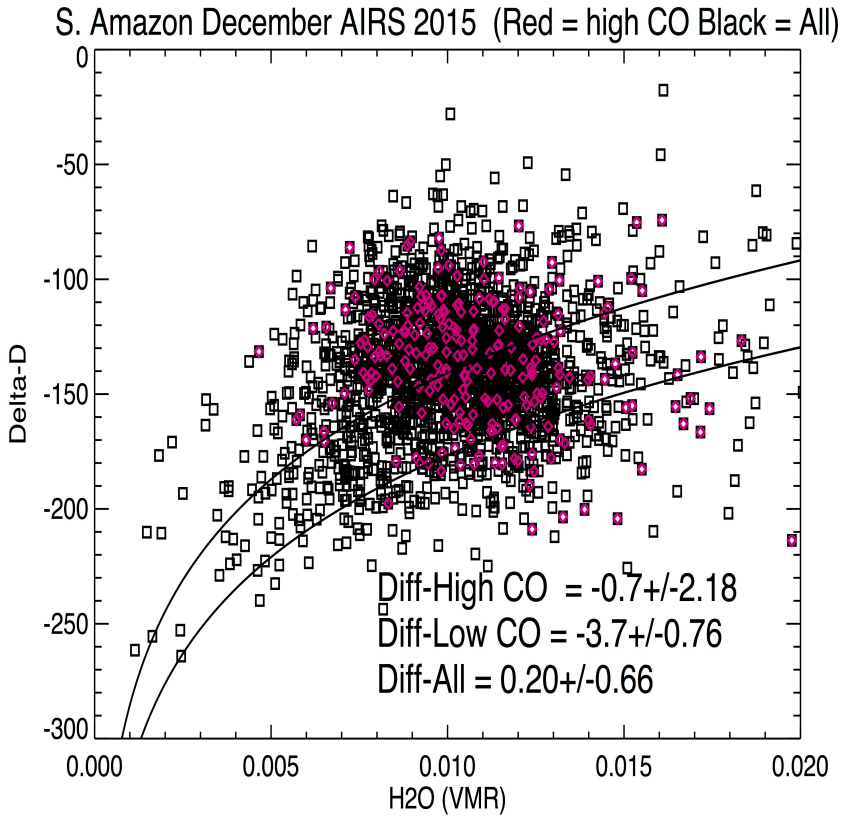
- These measurements can provide important clues for some of the primary outstanding puzzles related to the methane budget (the OH Sink), the changing tropical moisture balance, and the role of smoke aerosols on cloud formation and rainfall

- Currently we have three years of AIRS data and 5 years of TES data. We are In process in generating global coverage with 10X TES sampling beginning 2002 using AIRS, TES, and CRIS

AIRS Data shows a Tail of Two Amazon Rainy Seasons



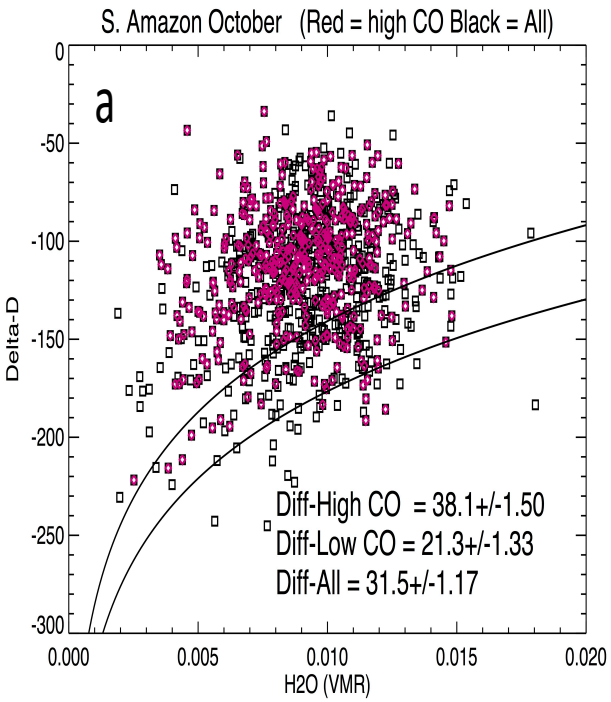
2013 is higher than average rainy season. Lots of convection, Lots of moisture from the ocean

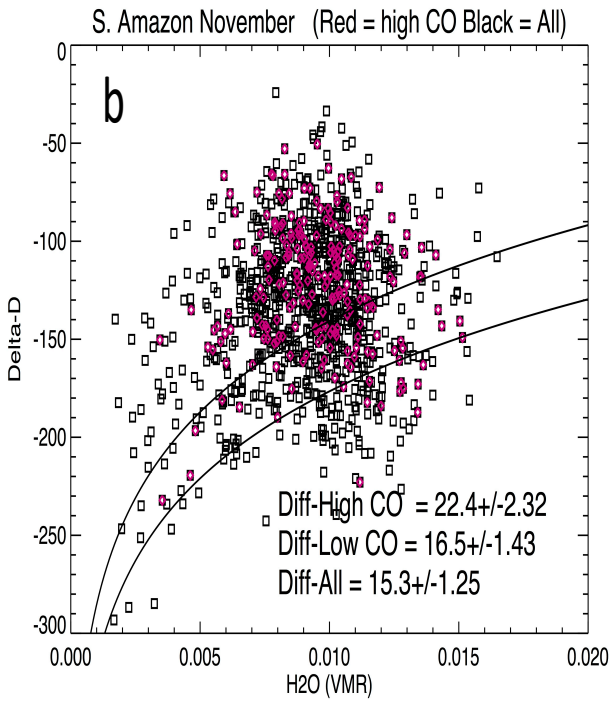


2015 is a dry year. Less Ocean Moisture, very little convection

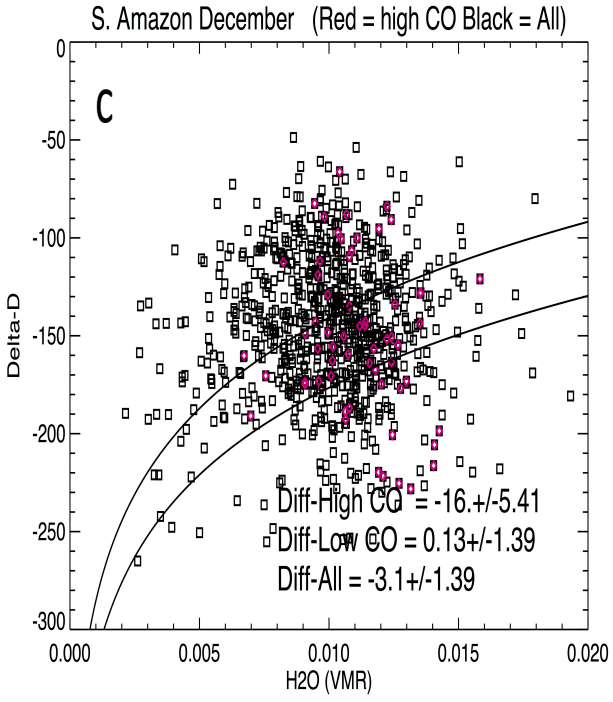
Why Do I Keep Showing CO With All These Figures?
How Does Smoke Affect Amazon Water Cycle?

Pre Rainy Season





Rainy Season



High CO more likely to be related to be above Rain Curve

Supports hypothesis that smoke aerosols stabilizes shallow convection before rainy season

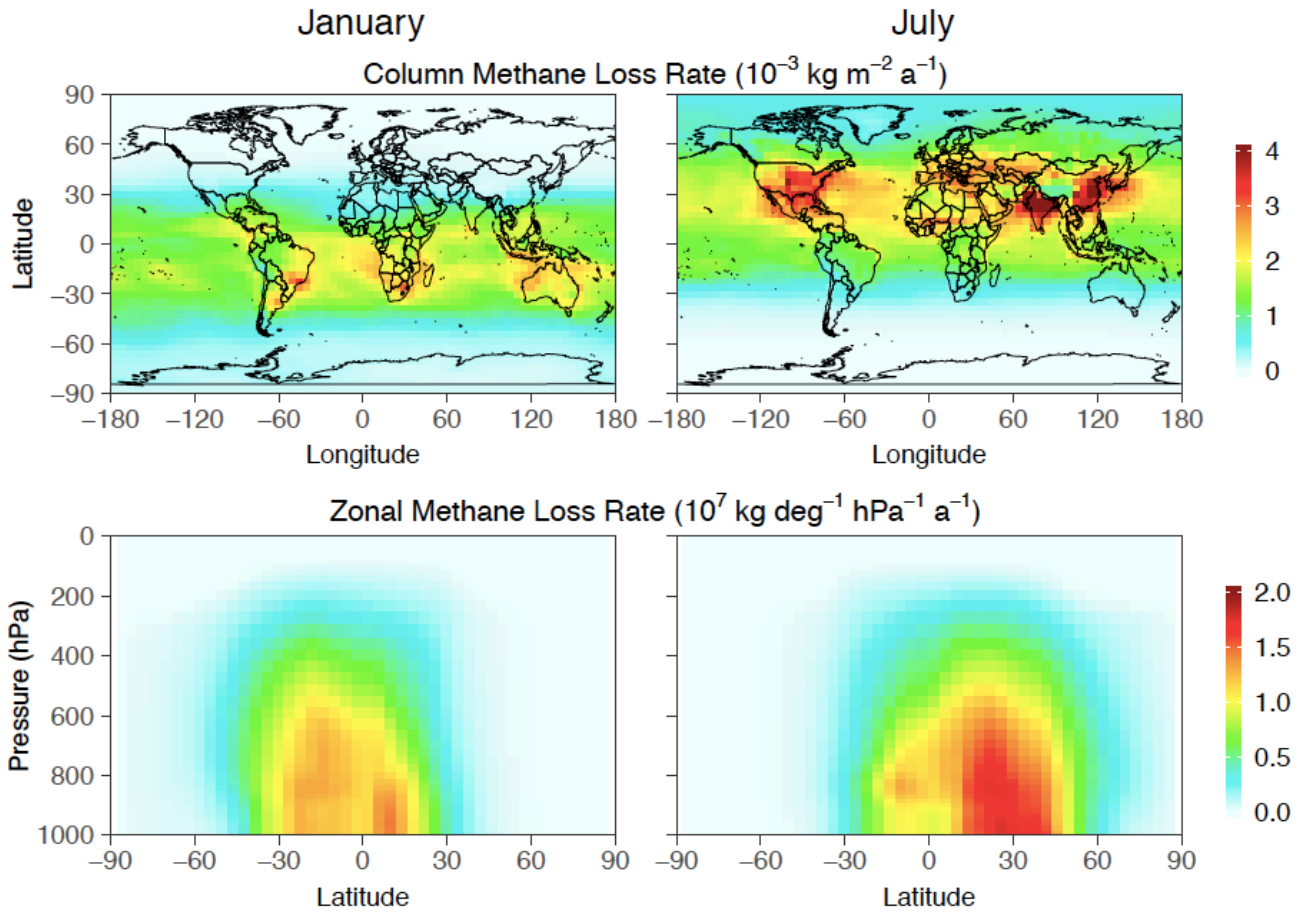
High CO more likely to be in Super Rayleigh Part of Distribution

Supports hypothesis that smoke aerosols invigorates convection once Rainy season starts

Can we use TIR Methane to monitor changes in OH (the methane chemical sink)?

$$\frac{dm_{CH4}}{dt} = E - k\overline{[OH]}\, m_{CH4} + \text{minor terms}$$

Distribution of tropospheric methane + OH loss rate (GEOS-Chem model)



Loss pattern has broad meridional and seasonal signatures,
distinct from emission signatures in inversions of methane satellite data
Combination an

Zhang et al. [2018]